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Review of studies that have quantified the economic benefits of interventions to increase walking and cycling for transport

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Summary of main points

- Walking and cycling for transport purposes has the potential to address a wide range of costly health and environmental issues, particularly the health burden of physical inactivity, and the need to address climate change
- There is consistent and growing evidence that increasing walking and cycling levels in the population also achieves substantial economic return over the long term.
- Evidence is emerging that investments in infrastructure that encourages walking and cycling demonstrate greater benefits than interventions that target behaviour change in the population.
- Quantified benefits vary widely depending on the range of direct and indirect outcomes considered and the methods used to value them.
- Outcomes most often considered are savings from reductions in health care costs, absenteeism, air pollution, congestion, and greenhouse gases, as well as gains in fuel savings.
- Direct economic benefits have also been reported to retail and other businesses from investing in walkable communities with high amenity values and proximity to frequently used destinations such as shopping, eating places, schools, and parks.
- Some harms are possible, particularly from increased rates of cycling injury, however, increased walking and cycling is likely to create a 'safety in numbers' effect and offset harms to some extent.
- Evidence from the literature is likely to be conservative as methods for evaluating benefits are complex, heterogeneous, and the field is still developing.
- In view of the recent literature, the range and extent of benefits to be derived from investing in walking and cycling infrastructure are currently significantly underestimated in New Zealand.
- To derive the maximum benefit from such investment, a whole system approach with region-wide integrated policy and planning is needed

Introduction

The health and the environmental benefits of an active lifestyle are well documented (US Department of Health & Human Services 1996; Warburton 2006; Gotschi 2011). The growing levels of concern about increasing obesity, rising rates of chronic disease, climate change, and the environmental impact of continuing to rely on fossil fuels for transport have made the case for promoting physical activity across whole populations even more compelling (Guo & Gandavarapu 2010; Gotschi 2011; Gortmaker et al 2011). Walking and cycling for transport is one way with considerable potential to address a wide range of these costly health and environmental issues (MacMillan 2012)

In New Zealand, physical inactivity is third only to smoking and diet as a modifiable risk factor for poor health It is associated with 9.5% of all deaths and is estimated to account for over 2600 deaths per year (New Zealand Public Health Association undated). New Zealand is not unique in this respect. According to Bauman et al (2008) the direct gross cost of physical inactivity to the Australian health budget in 2006/2007 was around $1.49 billion. Other Australian studies have reported that insufficient physical activity was the third largest single determinant on the Burden of Disease Scale in Queensland (Fishman et al (2011) and that inactivity was costing Australia $13.8 billion, traffic congestion a further $13 billion and car trips another $9.6 billion in air, water and noise pollution (Australian Bicycle Council 2011).

The effects of physical inactivity are not limited to health. Reliance on motorised transport also has far reaching environmental effects. They include such things as the loss of green spaces, an increase in heavy metals in road dust and contamination of storm water run off from road surfaces leading to increased ecological damage. Green house gas emissions from burning fossil fuels in transport contribute to global climate change, including flooding and erosion along coastal areas of New Zealand. Macmillan (2012, p. 14-54) provides a more detailed overview of these effects both on a local and global scale. In 2010 the transport sector was responsible for 19.4% of all emissions, 89.9% of which were from road transport. This was an increase of 1% from the previous year and an overall increase of 66.0% from 1990 (Ministry for the Environment 2012).

The health and environmental effects of reliance on car travel are linked (Swinburn et al 2011). Apart from the physical effects from inactivity, death and injury, and respiratory conditions linked to air pollution, there are a range of well documented effects on mental health and general wellbeing. Road traffic noise annoyance, traffic congestion and long commuting times contribute to stress, depression and anxiety, as do the opportunity costs of the time taken getting from one place to another (Dratva et al 2010; Ogilvie et al 2007; Frumkin 2002). Further, the demand for more and bigger roads to enable better traffic flows decreases green spaces, takes over productive land around urban areas, and reduces the ability of the area to sustain biodiversity (Trombulak & Frissell 2000; Gardiner & Armstrong 2007). Roading and increasing urban sprawl also affects mental health through community severance and social

isolation especially for disabled and low income people who lack easy access to reliable private transport (Thomson et al 2008; Urry 2002).
Policies that are likely to be most effective in mitigating the effects of road transport on climate change are also likely to be effective in addressing the range of impacts on physical and mental health (Woodcock et al 2009; Macmillan 2010; Haines et al 2007). Moreover, changing the built environment to encourage active transport options is known to reach population groups less likely to participate in leisure time physical activity (Fishman et al 2011). Investing in infrastructure that changes the built environment to make cycling and walking to every-day destinations like work and school convenient and safe has been shown to offset the health costs of sedentary lifestyles and to be more effective than individual behavioural interventions (Macmillan 2012, p. 33-34). There is evidence that such investment also provides a wide range of direct and indirect environmental, social, amenity and economic benefits (Gotschi 2011; Mackie 2010; Wu et al 2011; Turner et al 2011; Cycle to Work Alliance 2011; Guo & Gandavarapu 2010). A recent health impact assessment that investigated policies to reduce vehicle miles travelled in Oregon (Perdue et al 2012) similarly found that the most effective policies – limiting sprawl, increasing connectivity, and creating infrastructure for pedestrians and cyclists - had a consistent association with health benefits, particularly increased physical activity and decreased air pollution.

This paper highlights some of the recent literature in the field. A first section highlights studies published in the peer reviewed literature over the past few years; a second section focuses on reports from government agencies, and a third section lists other studies of interest that have assessed a range of economic benefits other than health. In each section, the main points of each study are described briefly, followed by a table that provides a comparison of the various outcomes and benefits from the findings. While the methods are outlined, in most cases these are complex and the full papers need to be read for the precise details.

Peer reviewed literature

Systematic review of economic analyses of transport infrastructure and policy effects on cycling and walking

Cavill et al., (2008) analysed 16 studies that investigated the economic evaluation of transport infrastructure intervention that included walking or cycling and the impact on health. Three studies were classified as high quality, two as moderate quality, and seven as low quality. The quality ratings were based on the amount of information given about the calculations and assumptions, with those studies rated as low quality providing poor justification for the benefits stated. Two studies were based in the United States and the rest in a variety of European countries. The range of health benefits covered by the various studies included reduced all-cause mortality, reduced mortality from heart disease, stroke, cancer, and diabetes, reduced injuries, and reduced medical costs. A few studies examined morbidity from diabetes, osteoporosis, depression, back pain, and reduced absenteeism. The health benefits are detailed in full in the article. Two main measures were reported: benefit-cost ratios, and the value attributed to each new cyclist or walker as the result of a policy or a piece of new infrastructure. For comparison of the values attributed to each new walker or cyclist, the local currency amounts from each study were adjusted into Euros, and ranged from €127-€1290. The wide variation was accounted for by the different assumptions made. The median benefit-cost ratio from all studies combined was 5:1 with a range from -0.04 to 32.5. The authors note that these figures should be treated with caution as the values are based on many different assumptions.

Intervening in the trip to work: a system dynamics approach to commuting and public health

Macmillan (2012) in her PhD study in New Zealand used participatory system dynamics modelling under five different scenarios to examine influences on mode share and link them to wellbeing outcomes over 30-40 years in Auckland. The scenarios were: Scenario 1 - no change (described as a "business as usual"); Scenario 2 - a regional cycle network with best practice policies; Scenario 3 - segregated cycle lanes on all arterial roads; Scenario 4 - self explaining local roads; and Scenario 5 - region-wide transformation combining the arterial and local best practice approaches (see p. 271). Changes modelled over the time period included mode share, air pollution, cyclist injury, physical activity, greenhouse gas emissions and fuel cost savings. All scenarios 2-5 showed benefits that outweighed the costs. Infrastructure costs ranged from NZ$45 million for scenario 2 to 630 million for scenario 5 and corresponding benefits ranging from $NZ 770 million to more than 13 billion. Benefit cost ratios ranged from 6 to 22 (see Table 8.7 p. 262 for details). Cycling mode share by 2051 ranged from 5% for scenarios 2 and 4, 20% for scenario 3, and 40% for scenario 5. The study concluded that an area wide change would require "… 3% of the annual transport budget [for Auckland] to start with, and would return approximately $20.00 in public health benefits for every dollar spent, under best estimate scenarios." (p. 284). Benefits such as increased mode share for pedestrians and public transport from the changes were not taken into account in the model, nor was the likelihood of increased safety for all road users through the slowing of traffic and the "safety in numbers" effect with fewer cars and more people cycling. The author noted that for such benefits to become a reality, a consistent, universal policy for the transport network as a whole would be needed.

Effect of increasing active travel in urban England and Wales on costs to the NHS

Jarrett et al (2012) estimated the potential effect of increasing walking and cycling on health care costs of seven diseases associated with physical inactivity: type 2 diabetes, dementia, cerebrovascular disease, breast cancer, colorectal cancer, ischaemic heart disease and depression. Health benefits were modelled over a period from 2012-2031 with the WHO comparative risk assessment method, which allows the changes in population health from modifying the population distribution of exposure to a risk factor to be estimated. Decrease in disease incidence was modelled according to the expected changes that would take place through increased physical activity with maximum plausible walking and cycling distances based on Copenhagen cycling statistics for 2010. Results of the modelling showed that irrespective of the sensitivity analysis used there would be a substantial saving to the NHS. At the most conservative a saving of around £6 billion and up to £27 billion over 20 years, with increased savings beyond 20 years possible because of the time lag in accruing benefit in the frequency of dementia and some types of cancer (p. 2203). The study did not take environmental benefits into account and did not examine the effect of increased physical activity on the prevalence of overweight and obesity.

Moving urban trips from cars to bicycles

Lindsay et al (2011) modelled the impact of increasing the proportion of urban kilometres travelled by bicycle for short trips (≤ 7km) instead of private motor vehicle on morbidity, mortality, vehicle pollutant and greenhouse gas emissions. The model, described in detail in the methods (p. 55), was populated using information from existing New Zealand data sets. The WHO Health Economic Assessment Tool was used to obtain estimates of reduced mortality and economic savings and to compare ethnic-specific mortality benefits for every 1,000 additional regular cyclists. Scenarios for varying proportions of short trips by adults (increases of 1%, 5%, 10% and 30%) were modelled showing mortality reductions from regular commuter cycling, and energy expenditure in terms of savings to the New Zealand health system and economy, health benefits from reduced air pollution, and reduction in greenhouse gas emissions. The potential increase in the number of vehicle versus cyclist injuries was also included. Results showed the benefit:cost ratio to be 3:1 for 1% substitution and over 40:1 if 30% of trips could be made by cycle instead of motor vehicle (p. 56). The mean annual economic benefit to all New Zealand from mortality reduction calculated using the WHO HEAT tool (WHO 2008) was $1.05 million per 1,000 cyclists. Benefits were greater for Pacific people ($1.3 million per 1,000 cyclists) and greater still for Māori ($1.8 million per 1,000 cyclists). The savings per kilometre per individual cyclist were $1.50 (all), $2.59 (Pacific) and $1.85 (Māori), and the savings per individual cyclist per year $1,4120, $2,441 and $1,747 respectively for the same categories (see Table 4, p. 57). Personal costs savings and indirect costs such as doctor visits and cost of medications were not included making the estimates likely to be conservative.

Health risks and benefits of cycling in urban environments compared with car use

Rojas-Rueda et al (2011) conducted a health impact assessment to assess the potential effects on health of a bicycle sharing scheme (Bicing) that was introduced in Barcelona in 2007 to promote sustainable transport, create a new individual public transport system, promote cycling as a means of transport, improve air quality and reduce noise pollution. Between March 2007 and August 2009, 11% of the municipal population subscribed to the scheme, and cycle trips increased by 30%, with more than two thirds of trips being used for commuting to work or school and over a third combined with another mode of travel. Mean distances cycled by each user were 3.29km on a working day and 4.14 km at weekends. Available data for Barcelona on travel by car, cycling, and Bicing use as well as air pollution, carbon dioxide emissions, and road traffic incidents were obtained and the WHO HEAT tool was used to quantify the benefits of physical activity. Effects of the initiative on mortality related to physical activity for the Bicing population were calculated both for two different age distributions (average 33 years and average age 48 years). For each year of operation it was estimated that 12.28 deaths had been avoided. This was made up of 12.46 deaths avoided from the increased physical activity, but reduced slightly by taking into account an additional 0.03 deaths from traffic injury and 0.13 from exposure to air pollution through cycling. The benefit-risk ratio of the project was calculated to be 77. Annual reduction in carbon dioxide emissions was estimated to be 9062 tonnes. A major difference in this study was that data from an intervention showing actual uptake of an intervention was used in the modelling rather than assumptions and scenarios about potential changes. The study did not take account of potential benefits of encouraging cycling outside the Bicing scheme, or any reduction of overall air pollution and traffic accidents because of the replacement of car trips by cycle. No monetised benefits were calculated, although the Bicing scheme was described as "low cost" (p. 4) .

Costs and benefits of bicycling investments in Portland Oregon

Gotschi (2011) examined the cost of investing in cycling infrastructure in relation to the economic value of health and other benefits in Portland, Oregon. Two types of health benefits were included: health care cost savings and the "monetised value of statistical lives" (p. S50). The calculations were based on three, four, and five fold increases in miles cycled under three different investment options: a basic $100 million plan; a more elaborate plan at a cost of $329 million that aimed to put 80% of residents within a developed bikeway, and a "world class" plan costing $773 million of very extensive cycling and walking infrastructure development. Using the model developed, either of the first two plans were calculated to break even by 2015, and the third by 2032. By 2040 the miles cycled were calculated to have converted to a total of $338, $491 and $594 million in the respective plans in health care cost savings . A detailed explanation and discussion of the methods used, their advantages and limitations is given in this paper. A particular strength of this paper was the availability of long-term data on cycling in the urban area of Portland from 1991-2008 and cost data from past investment in cycling. This reduced the number of assumptions needed and allowed the costs and benefits to be calculated with more certainty than would otherwise have been possible.

Economic evaluation of health-promoting built environment changes

Guo and Gandavarapu (2010) developed an analysis framework for estimating the best value in hypothetical built environment changes. Their model took Dane County Wisconsin as their environment and was populated using data from the 2001 Household Travel Survey, the 2000 census, and information on road networks, pedestrian and cycling facilities and other geographical and demographic data from the County Land Information Office. They considered construction costs, and compared them with physical activity and air quality benefits over a 10 year time-frame from 2002. Using their model, three measures of the transportation network were found to have consistent positive impacts on the distance each individual would be likely to travel on foot or by cycle: the provision of sidewalks (footpaths), the availability of a bike lane within a quarter mile of a person's residence, and the number of intersections per acre (used as a proxy measure for street connectivity). The authors concluded that best investments proved to be retail accessibility closer to households and the universal provision of sidewalks on all streets. Over ten years the total construction cost of the sidewalks was estimated to be $450.8 million against a health and air quality benefit of $845.85 million in 2002 dollars, giving a benefit to cost ratio of 1.87. This work built on the methods described by Boarnet et al (2008). Detailed methods and the assumptions used in the model are given in the paper.

Public health benefits of strategies to reduce greenhouse-gas emissions

Woodcock et al (2009) developed several different scenarios for London and Delhi to estimate the health effects of policies to increase active travel and reduce greenhouse gas emissions. Four different scenarios were used developed for each city and compared with a "business as usual" projection to 2030. The four scenarios were i) the use of low carbon emitting vehicles, ii) a large increase in cycling, a doubling of the distance walked and a reduction in car use; iii) a combination of both scenarios; and iv) as for iii) but assuming half the amount of walking and cycling. Outcomes assessed were physical activity, outdoor air pollution from transport fuels, and the risk of road traffic injury. Comparative Risk Assessment was used to estimate the change in disease burden. Each mitigation scenario was then compared with the business as usual 2030 transport scenario and the difference in the number of deaths used to estimate the effect of the mitigation strategy. More details of the methods used are given in the full text of the article and in an appendix to the online version. For London, all modelled scenarios showed reductions in the total number of premature deaths and Disability Adjusted Life Years (DALYs) that more than offset the increase in health burden from increased traffic injuries. There were more health gains from active travel than the use of low carbon emitting vehicles. The combined scenario (iii) was the most effective, with 7439 DALYs and 541 premature deaths per million population in London and 12,995 DALYs and 532 premature deaths per million population in Delhi over one year. Disease burden rose from traffic accidents in London because of the overall increase in the total distance walked or cycled (although walking and cycling became safer per kilometre travelled), but fell in Delhi. The disease burden from ischaemic heart disease was estimated to fall by 10-19% and 11-25% in London and Delhi respectively, and from cerebrovascular disease 10-18% and 11-25% respectively. There were smaller benefits from scenario iv) with shorter distances walked or cycled. The authors noted that they did not consider the effect of traffic noise on health, the effect of biofuels for transport on food availability, the health effects of the reductions in obesity from increased active travel, or the socio-economic distribution of the health gains. They also detailed the many uncertainties in their model structure and variables (p. 1939-1940), stating that they should be regarded as provisional until more accurate estimates become available. No monetised benefits were calculated.

Walking, urban design and health: towards a cost benefit framework

Boarnet et al (2008) assessed the magnitude of health benefits from urban design changes using a three step process:

- Inferring the change in walking distance from an urban design change
- Inferring the health benefits that would accrue due to increased physical activity
- Developing a monetised estimate of the value of those health benefits for consistent comparisons with project costs or with benefits from other policy

interventions in order to provide a monetised value to health benefits linked to changes in the urban environment.

Complex tables of total value and per capita value are given in the paper. For example, the estimated value of health benefits in a hypothetical resident neighbourhood of 5000 people from increasing retail employment density that increases walking was estimated to be between US$93 and US$3,666 per capita, and a total benefit of between $466, 574 and $18, 331, 955 overall. Some aspects of the paper are summarised in a more accessible form in a report by Litman (2011, p. 12).

The Boarnet et al paper (2008) was careful to note the limitations of the assumptions made about how much physical activity would increase as the result of any changes. They stated that planners must "…clearly articulate the assumptions made and possible pitfalls inherent in those assumptions" (p. 353). In addition they recommended that longitudinal studies were needed to gain more accurate knowledge about the persistence of physical activity behaviour and to investigate whether more active people self-select into walking-oriented neighbourhoods.

Table 1: Peer reviewed studies of economic benefits from investment in transport infrastructure to encourage walking and cycling

Author (Date)	Setting	Type of study and methods	Outcomes included	Monetary values ascribed to outcomes	Comments
Systematic review					
Cavill et al (2008)	USA/ Europe	Systematic review of 16 economic analyses of transport infrastructure and policy on walking and cycling	All cause mortality Mortality from heart disease Stroke Cancer Diabetes Injuries Medical costs	Median benefit-cost ratio of 5:1 (range -0.04-32.5) Value for each new walker or cyclist ranged from €127-€1290	Reported in Euros Wide variation is accounted for by the different assumptions made in the included studies
Original studies					
Macmillan (2012)	NZ	Participatory system dynamics modelling under five different scenarios to develop causal loop diagrams connecting influences on mode share with wellbeing outcomes.	Changes for each scenario over 30-40 years in: Mode share Air pollution Cyclist injury Physical activity Greenhouse gas emissions Fuel cost savings	Benefits outweighed costs for all scenarios modelled over the time span. Costs ranged from NZ$ 45 – 630 million for implementing the various scenarios with net benefits calculated to range from NZ$ 770 million to 13 billion. Benefit-costs ratios ranged from 6 to 22 for the individual scenarios	Other potential benefits not included in the modelling included reduction in light vehicle crashes resulting from reduced peak time traffic, and reduced morbidity from chronic diseases, as well as trip time reliability, reduced stress, improved water quality

				with the greatest benefit being from a region wide transformation combining best practice for both arterial and local roads.	and a reduced need for road widening and car parking.
Jarrett et al (2012)	UK	WHO comparative risk assessment method was used to estimate the cost savings from the reduction of disease burden through increased walking and cycling over 20 years. Maximum walking and cycling distances were based on Copenhagen statistics. Increase in road traffic injuries and treatment costs were derived from the literature	Reduction in the prevalence of and costs to the NHS of type 2 diabetes, dementia, cerebrovascular disease, breast cancer, colorectal cancer, depression, ischaemic heart disease	Health expenditure averted estimated to be between £17- £27 billion in 20 years with more benefit accruing after 20 years from the reduction in the frequency of dementia and some types of cancer. Greatest cost savings were estimated to come from reduction in type 2 diabetes, with nearly £1 billion per year averted by 2030.	Environmental factors, and reduction in the prevalence of obesity were not taken into account but authors suggest that even modest reductions in obesity could save and extra £2 billion per year
Lyndsay et al (2011)	NZ	Existing New Zealand data sets used in conjunction with WHO economic assessment tool to estimate mortality and economic savings and compare ethnic specific mortality benefits for ever 1000 additional regular cyclists for scenarios where cycling increased by 1%, 5%, 10% and 30% .	Reduction in deaths from increased physical activity and local air pollution from vehicle emissions Reduction in vehicle miles travelled Reduction in transport fuel Reduction in transport-related greenhouse gas emissions Increase in cyclist fatalities	With a 5% increase in cycling, an estimated 116 deaths saved from increased physical activity, 6 deaths from air pollution from vehicle emissions and 5 additional cyclist fatalities from road crashes. Mean annual benefit to society of between NZ$1.05 and $1.81 million per 1000 cyclists	Benefits for Māori and Pacific were greater than for the overall population. Health effects were limited to adults 20-64 years so are likely to be conservative. Authors concluded that the benefits of a transport mode shift from cars to

				A 5% shift from cars to cycling would save around $200 million per year. Estimated reductions of approx 223 million vehicle kilometres, 22 million litres of fuel and 0.4% reduction in greenhouse gas emissions.	cycling outweigh the harms and are likely to create other benefits not considered in the study.
Rojas-Rueda et al (2011)	Spain	Health impact assessment study estimating the effect on health of a public bicycle sharing initiative in Barcelona to which 11% of the population had subscribed between its inception in March 2007 and August 2009.	All cause mortality taking into account increased physical activity, and increased risk of exposure to air pollution and road traffic injury Savings in carbon dioxide emissions	Estimated 12.46 deaths avoided each year from increased physical activity Additional 0.03 deaths from traffic injury and 0.13 from exposure to air pollution. Overall annual number of deaths avoided was 12.28. Annual carbon dioxide emissions were reduced by estimated 9,062 tonnes	Major strength of this study was the grounding in a real life setting with observed measurements. Study did not account for: reduced morbidity due to increased physical activity, reduced exposure to traffic crashes and air pollution from fall in the amount of vehicle traffic, or benefits of decreased car use to the overall population
Gotschi (2011)	USA	Modelling study using the cost of past and future planned bicycle infrastructure investment in Portland. Oregon, and levels of cycling derived from data on observed	Health care cost savings Reduced mortality Saved value of statistical lives Fuel savings	By 2040 investment of $138-$605 million would result in health care cost savings of $388-$594 million, fuel savings of $143 million and savings in value	Authors noted that health effects of air pollution, amenity value of improvements, or increase in property values are likely benefits but are not

		trends and future projections for three future scenarios with different levels of investment and a 3, 4, and 5 fold increase in cycling.		of statistical lives of $7-$12 billion. Projected benefit cost ratios for health care costs and fuel savings were 3.8:1, 2.3:1 and 1.3:1 for the three scenarios.	considered in the model
Guo et al (2010)	USA	Development of an analysis framework for identifying the most promising strategies for health promoting built environment changes. Routinely collected data from Dane County Wisconsin, supplemented with land information and construction costs were used to model future increases in the miles walked or biked, reduction of vehicle miles travelled and the return on investment over 10 years.	Physical activity benefits, air quality benefits and combined economic return from adding footpaths at least on one side to every road in the county.	Estimated health and air quality benefits over 10 years of US$845.85 million in 2002 dollars. Total construction costs of US$450.8 million gave a benefit to cost ratio of 1.87	Adding footpaths was considered the most promising investment that would increase miles walked and reduce vehicle miles. The elimination of all roadways without footpaths in a neighbourhood was estimated to lead to 0.097 miles walked or biked per person per day. Increased retail accessibility was also assumed to lead to more physical activity and fewer vehicle miles.
Woodcock et al (2009)	UK/India	Scenarios developed for London and Delhi comparing "business as usual" by 2030 projections with one of four scenarios: i)use of low carbon emission vehicles; ii) a large increase in cycling, a doubling	Changes in physical activity, outdoor air pollution and the risk of road traffic injury resulting in: reductions in premature deaths reduction in years of life lost (YLL)	No monetised benefits calculated. See article by Jarrett et al (above) for monetised benefits based on the methods used in this article.	Increased active travel was shown to achieve greater health gains than lower carbon emitting vehicles. Authors noted their model

		of distance walked and a reduction in car use; iii) combination of both low emission vehicles and large increases in cycling and walking; iv) as iii) but with half the amount of walking and cycling.	reduction in years of healthy life lost as a result of disability (YLD) reduction in disability adjusted life years (DALY)	All scenarios showed health benefits that outweighed harm from traffic injury. Modelling showed that the combined scenario (iii) would be the most effective saving 7439 DALYs and 541 premature deaths in London and 12,995 DALYs/532 premature deaths in Delhi respectively in one year.	should be considered provisional because of many uncertainties a Extent of generalisability to smaller cities is uncertain Health effects of road traffic noise, reduction in obesity was not considered nor was the socioeconomic distribution of effect of the health gain.
Boarnet et al (2008)	USA	Geocoded travel diary data from Portland Oregon used to derive the magnitude and statistical significance of the link between urban design variables and walking distances. Regression analysis explaining how much individuals walk based on the characteristics of the neighbourhood where they live. Inferences about the size of health benefits and estimated monetized benefits to the health system	Reduction in mortality risk from increased walking increases associated with urban design changes (eg. increased in population density near central business district, employment density, greenfield neighborhoods, etc) Annual lives saved and monetised value of lives saved	Complex calculations showed benefits ranging from US$2-24 million depending on the type of design change, different estimates of the number of more active people, and the distances walked.	Noted that planners must clearly describe the assumptions made in such modelling, particularly relating to the amount of physical activity that would be generated as a result of infrastructure changes

Reports from government agencies

This section details four recent reports that have been commissioned by government departments or local authorities: two from Britain, and one each from Australia and New Zealand. While these do not have the same level of research rigour as the studies outlined above, three of the four report on results of projects that have already been implemented and have provided insights into what has happened from changes in infrastructure investment in a way that cannot be done by modelling studies. A table at the end of the section shows their findings in brief.

Value for Money: an economic assessment of investment in walking and cycling

This comprehensive and recent review of evidence from both peer reviewed and grey literature in the UK and beyond (Davis, 2010) was compiled for the NHS Bristol and Bristol City Council. The review found a consensus among experts in many OECD countries that significant public health benefits can be realised through greater use of active transport modes. It noted that cost benefit analysis is of growing importance in recognising the costs of physical inactivity and that there is a need to steer transport policy in urban areas so as to promote effective interventions. The major finding of this review was that almost all the studies identified from the UK and beyond reported economic benefits of walking and cycling interventions which averaged 13:1 across all the studies reviewed. For UK interventions alone the average figure was even higher at 19:1. The individual interventions and the cost benefit analysis that are covered in the report include:[1]

- A canal towpath in London that was transformed into a high quality route, with improved surface quality and connectivity. Combined with a congestion charge in London, the intervention led to considerable increases in use resulting in:
    A benefit cost ratio of £24.1:1
    Savings of £5,487,130 through reduced absenteeism
    Savings of £28, 537,854 due to increased physical fitness (based on numbers of preventable deaths).
- Improved cycling and pedestrian infrastructure links to schools in three different British cities resulted in a cost benefit ratio of 29.3:1 in Bootle, 32.5:1 in Hartlepool, and 14.9:1 in Newhaven.
- Investment in walking and cycle networks in three Norwegian cities was assessed as having given a net benefit/cost ratio of 4.09:1 in Hokksund, 14.34:1 in Hamer, and 2.94:1 in Trondheim.
- The City of Copenhagen adapted The Danish Ministry of Transport's manual for calculating cost-benefit to assess cycle projects. They calculated that there was a gain for society of 1.22 Danish Kroner per kilometre cycled and a societal loss of 0.69 DK per km driven by car. Other findings were that in cost benefit terms the health and life expectancy benefits of cycling are seven times greater than accident costs.

[1] The review also listed benefits from the Cycling Demonstration towns which are covered in more detail in the section below.

The final conclusion of this review was that investment in infrastructure to increase walking and cycling was likely to be a “best buy” for population health, for the health system, as well as for the transport sector. The original studies referred to are all referenced in the review and need to be read for the complete details.

Economic benefits reported from the British Cycling Demonstration Towns

The British Cycling Towns project was initiated by Cycling England and the UK Department for Transport to encourage cycling and physical activity.[2] Six towns of around 100,000 population each were selected to each receive a government grant of £5 per head of population per year for three years between 2005 and 2008. This needed to be matched by the respective local authorities so that the level of investment was at least £10 per person per year. Most towns undertook a range of initiatives beyond those that were directly funded including additional interventions in schools and investment in cycling infrastructure. An analysis and synthesis of the evidence (Sloman et al., 2009) reported on the impact of the first phase of the interventions.

Automatic and manual cycle count data, results from surveys, and data on travel to school showed a consistent picture of an increase in cycling compared to baseline over the three years for all six towns. There was no corresponding increase in comparison towns that had not received the intervention. Cycling rates did not increase immediately but built up gradually over the three years.

Economic benefits were assessed using the WHO Health Economic Evaluation Tool (HEAT) (World Health Organisation, 2008) modified to take account of the number of new cyclists and time spent cycling as input values. The analysis found a maximum annual benefit after five years of £8.9 million per year. After taking into account the costs of grant money by Cycling England/Department of Transport (£2.8 million per year), and the funding by (an average of £3.4 million per year for three years), the analysis found that each £1 invested returned a value of £2.59 in decreased mortality of adults aged 20-60 years alone.

Following this analysis, in January 2008 a further 11 towns and one city were added to the demonstration project with £140 million in funding over the next three years. A mid-term review (Cycling England, 2010) that took a wider range of impacts into consideration in a broader economic analysis reported that the cost-benefit ratio was estimated to increase to 2.6-3.5:1 over a decade. Using this ratio it was estimated that over 10 years the six original towns would save:

- £45 million from reduced all-cause mortality for adults aged 20-60 years.
- £7 million from decongestion
- £1-3 million from reduced absenteeism.

The details of the methods used and the assumptions made in calculating these benefits are given in the full text of the report (p. 24-25). The analysis did not attach any monetary value to any benefits gained by children and young people, people aged

[2] For further details see website at http://www.dft.gov.uk/cyclingengland/cycling-cities-towns/

over 60 years, or any other gains arising from reduced absenteeism, congestion, improved air quality, improved journey ambience and journey time. There was also no consideration of potential benefits in prevention of obesity, improvements in mental health, physical development benefits, social benefits, tourism applications, and the potential reduction in the number of traffic accidents. A background review (McDonald, 2007) for Cycling England that examined individual examples of cycling investment within the demonstration towns reported that new cycling infrastructure more than pays for itself, but must be supported by a total package of measures. Substantial investment is required to attract new people to cycling rather than just getting existing cyclists to cycle more Physical structures needs to be supported with training and marketing, but equally, training and marketing will not deliver benefits unless there are safe and convenient cycle routes. The full benefits in reducing congestion and pollution can only be achieved within a broader approach of discouraging car use (McDonald, 2007, p.84).

Getting Australia Moving

This report (Bauman et al., 2008) was commissioned by the Australian Department of Health and Ageing to estimate the value of the current bicycle commuting trips in Australia based on the 2006 census. Along with health, environmental, cultural, safety, and regulatory factors the report considered the economic benefits of cycling participation. Rather than using the WHO HEAT tool approach to calculate economic benefit, this report used a model developed in Australia (Econtech, 2007) to estimate the direct value of cycling. This model limited its calculations to the direct gross and net costs of physical inactivity to Australia in the form of monetary values but also provided a general discussion of some of the likely indirect and intangible costs of physical inactivity that could not be included in these calculations. The value attributable to physical inactivity was based on an estimated prevalence of 54.2% of the population between 18 and 75 years being classified as inactive,[3] with the cost of each inactive person to the health budget being calculated at A$198.57 per year. Based on these figures, the report concluded that the economic benefit of commuter cycling was A$144.3 million per year and that current commuter cyclists at the time of writing saved the economy A$63.9 million in reduced congestion costs and A$72.1 million in reduced health care costs.

Benefits of new and improved pedestrian facilities

Turner et al (2011) conducted a before and after study of new or improved facilities in eight different locations in New Zealand cities that were known to create difficulties for pedestrians. Five sites were in Christchurch (pre-earthquake), two in Hamilton, and one in Auckland, and most were near schools. Improvements varied from kerb extensions and refuge islands to controlled crossings, either with signals or adapted for a school patrol. Before and after counts of trends in pedestrian numbers were undertaken as well as before and after surveys assessing pedestrians perceptions of safety, delay, and directness, key factors that were likely to influence pedestrians' crossing preference. Pedestrian use increased in seven of the eight sites, ranging from

[3] Inactive was classified as not reaching the minimum level of physical activity levels of 30 minutes of moderate physical activity at least 5 times per week.

7% to 90%. Overall, it was noted that the kerb extensions and refuge islands gave the largest increase in numbers followed by the kea (school patrolled) crossings. A benefit of $2.70/km for new pedestrian trips derived from the New Zealand Transport Agency Economic Evaluation Manual (2010) was noted in the report. However, in spite of referring to this value the report did not carry out a cost/benefit analysis of the various improvements. It should also be noted that the improvements described were isolated to an individual problem area in each location rather than being part of an upgrade of walking or cycling facilities over a wider area.

Table 2: Reports from government agencies

Author	Country and organisation	Type of report	Outcomes included	Economic benefits	Comments
Davis (2010)	UK NHS Bristol and Bristol City	Comparison of the cost-benefit of six infrastructure projects (4 in UK, 1 Norway, 1 Denmark) to increase cycling. Tables of annual value attributed to one regular cyclist and numbers of cyclists needed to achieve a 1:1 cost benefit ratio for different levels of investment cost.	Reduced mortality Life years saved Reduced absenteeism Increased physical fitness Reduced road traffic casualties	Cost benefit ratio 19:1 averaged across all projects (range 10:1-32.5:1) No overall monetised value calculated	Health outcomes varied across the six projects; Environmental benefits were not considered Separate table proposes £600 overall benefit for each additional cyclist replacing 50% of car trips with cycling over one year. Data tables used for deriving cost benefit ratios attributed to SQW Consulting (UK). Full details of assumptions made are not given in the report.
Sloman (2009)	UK Department for Transport and Cycling England	Analysis of evidence from six Cycling Demonstration Towns using WHO HEAT tool.	Reduced mortality Reduced congestion Reduced absenteeism Reduction in proportion of adults classed as inactive	£2.59 per each £1 invested in decreased mortality alone. Mean annual benefit of additional cycling £4.5	10% reduction in proportion of inactive adults; Not considered: health outcomes for children or older adults; air quality,

				million/year; total saving of £45 million over ten years if all new cyclists continue cycling	morbidity, social benefits, or reduction in traffic accidents
Bauman (2008)	Australia Department of Health & Ageing	Assessment of current value of cycling to the Australian health system using modelled cost of each inactive adult person to the health budget per year and 2006 census data on numbers cycling to and from work	Current overall saving to the economy from commuter cycling Current saving from reduced congestion costs Current savings from reduced health care costs	Cost of each inactive person: A$198.57/year Overall economic benefit of commuter cycling: A$144.3 million/year; A$63.9 million/year saving in reduced congestion; $A72.1 million/year saving in health care costs	Based on modelling of the cost of each inactive person by Econtech (2007) Barriers and facilitators to increasing cycling and recommendations also included
Turner (2011)	NZ NZ Transport Agency	Before and after study of the benefits of eight new or improved pedestrian facilities in Hamilton (2), Auckland (1) and Christchurch – pre earthquake (5)	Pedestrian counts Perception surveys of safety, delay, and directness	Pedestrian use of all sites increased (range 7% -90%) Kerb extensions, refuge islands and kea crossings (school patrolled) gave the greatest increase Kea crossings had the highest perception of safety.	Improvements were to isolated locations rather than an overall upgrade of a wider area. Monetised benefit of $2.70/km for each new pedestrian trip from the NZTA manual was cited but no cost-benefit ratio calculated

Other examples of benefits from infrastructure that promotes walking and cycling

This section highlights several recent examples of positive benefits other than health or environmental outcomes that are being recognised as a result (or potential results) from investing in infrastructure development to encourage walking and cycling Three look at economic advantage to property owners from investing/owning locations in walkable areas, while the fourth considers the employment and economic gains to be realised from building walking and cycling trails. Table 3 at the end of the section shows their findings in brief. .

Benefits to businesses from walking and cycling traffic in retail environments

A study commissioned by the Heart Foundation of Australia (Tolley 2011) featured 16 case studies of streetscapes in Britain, the United States, Australia, and Canada showing the positive financial benefits to be had from improving retail environments. One example case from London, was able to show that improvements in street design quality had added up to 4.9 percent to retail rents of all shops and premises in the area (CABE 2007). The paper noted that it was no coincidence that the top three "Liveable Cities" in the world – Melbourne, Vienna and Vancouver – are regarded as amongst the most walkable cities anywhere (Tolley 2011, p. 15). This report found that people on foot or travelling by cycle are likely to visit more often, stay longer in a well designed pleasant area with other foot traffic and therefore spend more than people who drive to kerbside parking to make a specific purchase. They also showed that vehicle traffic restraints and emphasis on walking and cycling are essential to the success of revitalisation strategies. The paper also drew attention to a number of other studies, including one from New Zealand (Allatt et al 2012), that has consistently found that retailers significantly overestimate the number of their customers who travel by car and often do not understand the importance of crossings, wide pavements and reduced traffic flow for shoppers.

The walkability premium in commercial real estate

A detailed paper from researchers at the University of Arizona and Indiana University (Pivo and Fisher 2010) investigated the impact of walkability on market values and investment returns for more than 4,200 office, retail, apartment, and industrial properties in the United States. Walkability was based on a walkscore rating tool (www.walkscore.com) which calculates the degree to which any property within the US is likely to encourage walking trips from the property to other destinations (p. 2) National data on property values between 2001 and 2008 were combined with the walkability ratings of those properties to discover how those with the highest walkability scores compared with those with lower ratings. The investigators' primary aim was to establish whether low financial returns in such area might be a potential barrier to property investors. They were able to demonstrate, however, that greater walkability gave higher values and higher net operating incomes for office, retail and apartment properties, though had no effect on industrial property. The presence of desired destinations such as grocery stores and eating places within walking distance was found to be the most important factor for walkability. The study concluded that walkable properties have the potential to generate returns as good as or better than other property investments. Benefits that might accrue in air quality, traffic safety, and energy conservation were not taken account of in their calculations though the authors acknowledged the environmental, health and social benefits of walkable neighbourhoods and cities. Full details of the methods used are included in the paper.

Economic and employment benefits from walking and cycling trails

A study in the United States (Garrett-Peltier 2011) looked at the employment benefits that could accrue from investing in walking and cycling infrastructure. The analysis took into account the jobs that were created in all the phases of design and construction of facilities including the manufacturing of materials and equipment. They also noted that the facilities once built would bring significant benefits to individual communities. Details from 58 walking or cycling trail projects from eleven cities throughout the United States for which adequate data could be obtained were analysed. Job creation was assessed in terms of the number of full time equivalent positions created for each $1 million spent. Across all projects the average level of job creation was around nine jobs, with cycling infrastructure projects creating the most (11.4 jobs per million spend) and roading-only projects such as repaving or widening roads the least (7.8 jobs per million spent). The study concluded that when planners are "… confronted with a decision of whether or not to include pedestrian and/or bicycle facilities in transportation infrastructure projects, [they] should do so, not only because of the environmental, safety, and health benefits but also because these projects can create local jobs." (p. 9).

The study did not take account of revenues and jobs for local bike shops and other businesses, employment in maintenance of the facilities, or tourism benefits for cycling and walking trails outside urban areas. These have been considered elsewhere. Snyder (undated), for example, listed economic benefits to local businesses from eight different studies of walking and cycling investments in the United States which showed potential benefits in areas such as increased sales tax as visitors were likely to spend on food, lodging, clothing, equipment, and accessories, while the government would benefit from the increased sales tax. Additionally, businesses and properties in areas adjacent to such facilities were likely to rise in value. Similarly a recent report from the Australian Bicycle Council (2011) noted that the Australian bicycle industry employs 10,000 people and generates $139 million annual income tax revenue, that bikes and accessories are worth $1 billion a year, generating $100 million GST revenue, and that cycle events and tourist trails generate $254 million a year.

How walkability raises home values in US cities

Cortright (2009) investigated the impact of walkability on housing values across 95,000 real estate transactions in fifteen cities in the United States. Using Walkscore (www.walkscore.com) he found a strong correlation between walkability and variations in home values. A one point increase in Walkscore (scored out of 100 points) typically increased the value of a residential property by between $700-$3000.

The author notes that “…cities revolve around the variety of consumption choices and experiences they provide, the relative ease of accessing those choices and the opportunity to discover new goods, services and experiences” and goes on to quote the replacement of a mall in Colorado with a mixed use development of “… a commercial and residential district with 1300 apartments, 200 condominiums and single family homes, offices, and a neo-traditional main street.” (P. 26).

Table 3: Other examples of potential benefits from infrastructure that promotes walking and cycling

Tolley (2011)	Australia National Heart Foundation of S. Australia	Outlines16 Case studies in USA, Canada, UK, Australia of the financial benefits to retailers and residents in making commercial streets more walking and cycling friendly	Increased retail rent values Increased pedestrian and cyclist activity Increased amenity value of area Increased economic activity Reduction in traffic accidents	No monetised benefits No cost-benefit analysis	Individual case studies assessed widely different outcomes with overall positive benefits reported. Individual studies are referenced and would need to be read for details of how calculations were made.
Pivo & Fisher (2011)	USA University of Arizona/Indiana University	Assessed effect of “walkability” on commercial real estate values using Walk Score (www.walkscore.com) and national data on real estate values	Market value and investment return for 4,200 office, retail, apartment, and industrial properties across the US according to walk score.	A 10 point increase in walkability (100 point scale) for office, retail and apartment properties had a premium of between 1-9%. Properties with a walk score of 80 were worth anywhere from 6-54 % more than properties with a walk score of 20. Industrial properties did not have a walkability premium.	Did not take into account public health outcomes, air quality, traffic safety or energy conservation.
Garrett-Peltier (2011)	USA University of Massachusetts Political	Gathered detailed cost data on capital cost of building transport infrastructure from 58 projects in eleven cities across the US and estimated the employment effect using an	Number of full time equivalent positions created per US$1 million spend on infrastructure	Cycling infrastructure created a mean 11.4 positions; Pedestrian 9.9 positions	Job creation included direct jobs, indirect jobs (manufacturing or supplying products used in building the infrastructure) and induced jobs (spend

	Economy Research Institute	Input-Output model from the US Bureau of Economic Analysis		Mixed cycling/pedestrian 8.4 positions Roading 7.8 positions	by workers in the direct and indirect jobs)
Cortright (2009)	USA CEOs for Cities http://www.ceosforcities.org/	Data from 95,000 real estate transactions in 16 cities across the US rated by Walk Score and price.	Market value of homes in relation to their walk score	Positive correlation between walkability and housing prices in 13 of 15 markets surveyed. A one point increase in walk score was associated with US$700-$3000 increase in home value.	Noted that Walk Score measures opportunity not actual activity. Study was controlled for size of home, age, neighbourhood income level, and proximity to employment and urban centre.

Methodological approaches

Measuring the impact of changes to encourage walking and cycling is difficult particularly as the full effect may take a long time to become apparent. Obvious difficulties include the variety of methods used to quantify the extent of mode change, and the assumptions made about the change in disease incidence, the extent of the change to mode share, how societal costs of disease burden are calculated and the difficulty of generalising the findings of any particular study to another context across health systems and countries. Robust methods of calculating the direct and indirect benefit in monetary terms and adjusting them to different contexts is complex and methods are still developing. Discussing the methodological approaches is beyond the scope of this paper. The WHO HEAT tool for cycling (WHO 2008), however, is worth describing briefly because it has been used so widely. It provides a method of calculating the economic value of the reduction in adult mortality gained from investment in cycling infrastructure that creates modelled levels of cycling uptake. It can then be used in a cost benefit analysis. It can also be used to value the mortality benefits from current levels of cycling in a particular workplace, city, or country. The tool is based on evidence of a 0.72 relative risk all-cause mortality among regular commuter cyclists aged 20-60 years relative to the general population. The guide to using this study is at http://www.euro.who.int/__data/assets/pdf_file/0011/87482/E90948.pdf .

The HEAT tool can be used to calculate:

- Maximum annual benefit
- Savings per km cycled per individual cyclist per year
- Savings per individual cyclist per year
- Savings per trip
- Mean annual benefit
- Present value of mean annual benefit

The HEAT tool is limited in that the only health benefit considered is mortality for adults from 20-60 years. It does not therefore take into account any benefits to younger or older cyclists, any other health benefits, or any environmental benefits. .

The New Zealand Transport Agency has previously done work on valuing the expected economic benefits of improving walking and cycling facilities (New Zealand Transport Agency 2010; Genter et al 2008). In their 2010 manual they calculated a composite benefit for new pedestrian or cycling facilities of $2.70 and $1.45 respectively for each new user and assuming an average per trip distance of 1km per for pedestrians and 3km for cyclists. Benefits considered were health and road traffic reduction benefits for walking and health, safety, road traffic reduction benefits for cycling. The work by Lyndsay et al (2011) and Macmillan (2012) however, as well as the international studies reviewed above suggest that the NZTA calculations are likely to considerably underestimate the health and economic benefits that can be derived from investing in active transport infrastructure and should be reviewed in the light of the subsequent studies. Moreover, as noted by Macmillan (2012), the NZTA has an emphasis on workplace and school travel plans (see also Mackie 2010 for example) which focus on individual behaviour change, rather than addressing the structural issues that make it difficult for individuals to change to more active modes of travel and may also, if unaccompanied by suitable and safe infrastructure for walking and cycling, travel plans may put pedestrians and cyclists at increased risk of injury (Macmillan 2012 p. 86

Limitations of this overview

This paper is an overview only rather than a comprehensive examination of the contribution that investing in walking and cycling infrastructure can make to health, the economy, the environment and society in general. A particular omission is any discussion of equity issues in transport, which are clearly relevant, but have been beyond the scope of this paper.

Expert guidance was sought so as to include the most relevant peer reviewed studies. The full reports of these studies should be read for the many detailed methodologies used in these studies. The remainder of the documents provide firstly, selected examples where government departments have investigated the actual uptake of active transport options and considered the costs and benefits, and secondly, an examination of an outcome of interest not considered elsewhere. The quality of the assumptions made in these non-peer reviewed documents has not been critically assessed.

Conclusion

This short overview of some of the recent work on economic benefits of active transport infrastructure consistently shows that built environments that encourage walking and cycling have a wide range of benefits, including the potential for substantial economic benefits. Moreover, many of the studies reviewed above commented on the additional benefits that were likely to accrue from changes to infrastructure over and above those that they were able to include in their calculations.

Two of the most recent studies reviewed above (Lyndsay et al 2011; Macmillan 2012), were done in New Zealand. Their findings are strikingly consistent with international investigations, and are made even more compelling because national data is used and their conclusions are based within the New Zealand health and economic context. As noted above, their findings advance work done in this country provide new impetus to update the work done by the New Zealand Transport Agency on valuing the benefits of increasing the investment in walking and cycling infrastructure to achieve both health and environmental gains.

Methods of calculating benefits and the types of benefits that can be quantified are still developing. For these to become increasingly reliable within the New Zealand context it is important to have reliable and consistent data recorded over a sufficient length of time. A strength of four of the studies reviewed above (Gotschi et al 2011; Boarnet et al 2008; Rojas Rueda et al 2011; Sloman 2009) was that they had local data on uptake resulting from transport interventions so that modelling of future economic and health benefits was more surely grounded in the local context and therefore less open to charges of uncertainty. These are “natural experiments” that will gradually add to evidence of how health effects can be created or destroyed by changes in infrastructural investment and wider public policy (Ogilvie et al 2006).

One New Zealand example is the URBAN study[4], the local arm of the International Physical Activity and Environment Network study (IPEN). This study has already added to the information available in a New Zealand context, (for example, Badland et al 2012). Similar work is being done in West Australia in the RESIDEntial Environment Project (Giles-Corti et al 2007; Giles Corti et al 2008).

The synergies between policies that promote health, support environmental sustainability, and reduce congestion would seem too clear to ignore, given the fact that they are economically attractive and have a wide range of other benefits as yet to be fully quantified. As the above overview has shown, when it comes down to implementing such policies, the "best buy" is investing in infrastructure that makes walking and cycling a convenient and safe option for the majority of the population. Integrated policy and planning at a system level, "… a universal approach that progressively and proactively transforms both arterial and local roads" (Macmillan, p. 284) however, is needed to capitalise on the benefits.

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[4] See http://www.massey.ac.nz/massey/research/centres-research/shore/projects/urban-study.cfm for an overview of the wider study

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